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ASTRONOMICAL RESEARCH DURING 1929

(Retiring President's Annual Address, February 4, 1930.)

By W. E. HARPER

Before beginning my address may I have the privilege of expressing my appreciation of the generosity of the members of the Royal Astronomical Society of Canada in having elected me last year as their President for a second term, and this too in spite of the fact that some 3,000 miles separated me from the Headquarters of the Society, making it impossible for me to shoulder many details of office. In consequence, these were laid on others' shoulders and my best thanks are due to the Vice-President, Dr. R. K. Young, who has done most of the work, while I have been accorded the honour.

Popularizing Astronomy. I referred in my last address (see JOURNAL for March, 1929) to the need of making the Editor's task as light as possible by furnishing him with suitable material to pick and choose from. I think the JOURNAL at present is meeting the need for which it was intended, is exceedingly well got up, and reflects much credit on the Editor, Professor C. A. Chant. Realizing, however, that our Society should try and reach a wider audience than comes in touch with astronomical science through our meetings in various Centres or through the columns of our JOURNAL, or even the unseen listeners over the radio, your president was able to interest a syndicate of newspapers the past year to publish brief popular articles on astronomy. These, as many of you know, are prepared by some of our leading members and appear fortnightly in the Southam Newspapers in Hamilton, Ottawa, Winnipeg, Cal-

gary, Edmonton and Vancouver. The Victoria *Colonist* and Halifax *Herald* have also purchased the rights to the series and are using the articles. Other papers, we trust, will follow suit. Two benefits accrue. Firstly, a wider circle of readers in Canada is becoming interested, as the articles are such as to attract the average person. Secondly, the treasury of our Society benefits financially for each article published more than a Life Membership costs. The hope is expressed that some of such monies might well establish a fund to provide some instruments for research upon a simple problem in which a number of our members from the Atlantic to the Pacific could have a share.

It seems to be the custom for the Retiring President to give in his address at this meeting a résumé of the progress achieved in the science during the year just closed. I wondered if I could not break away from the custom and choose something else, but I found that almost every subject upon which I might hope to say something had been touched upon recently in your gatherings. Rather reluctantly, therefore, I have fallen back upon the customary topic. The preparation of the material for such an address would be much easier if one could only postpone it for a month or so, for then the valuable summaries which are given in the *Monthly Notices* of the R.A.S. would be available. However, the digging out of the material at first hand and the necessary sifting and condensing of that which would be suitable to present on this occasion is an education in itself. Particularly is this true in my own case for in the rush of observational and computational work I find all too little time to even read, much less digest, what other similar workers are doing.

I shall follow roughly the plan I adopted last year and deal first with

1. The Solar System

Solar Activity. The average daily number of sun spots reached a maximum in 1928, the Zurich numbers rising from 5.8 in 1923 to a maximum of 77.8 in 1928. When the areas of the sun spots are made the basis, however, the curve of activity has two maxima, one in 1926 and one in 1928, with a slight depression for 1927. The

maximum is thus somewhat of a rounded form, but 1928 would probably be a better date to assign than 1927 as stated in my address of a year ago.

Taffara at Catania, Italy, from a study of the curve of solar activity as given by all its forms,—such as spots, prominences, faculae, etc.—shows that there is a tendency for successive maxima to be alternately high and low. Now from the work of Hale and his associates at Mount Wilson we have learned of the alteration of the polarities of sun spot groups in succeeding cycles as if the true period were just double the 11½ year one generally accepted. Taffara's findings, that a high maximum alternates with a low, is therefore in harmony with the longer period hypothesis.

Stetson is reported as stating that a 15-month cycle is superimposed on the longer cycle. Investigations by him and Pickard seem to show that radio reception is poorest when sun spots are active and thus radio reception should improve during the next few months.

It has long been known that at the beginning of a sun spot cycle the spots appear in high latitudes and gradually move towards the equator, dying out as minimum approaches at a latitude of about 10°. Statistics are now being kept as to their distribution in longitude also, and it is learned that the activity is greater in one quadrant than in the others, but that a gradual shifting to other quadrants appears to be the rule.

While we are definitely on the downward slope of the curve nevertheless large spots have recently been seen and may naturally be expected at occasional intervals. In the year 1920, three years after the maximum had passed, the most extensive stream of sun spots that had been witnessed in fifty years was a feature of the solar surface.

Solar Eclipse. Plans were made by several American, English and German astronomers to photograph the total solar eclipse of May 9 last, in Sumatra and other South Sea regions. Partially cloudy skies militated against the success of the English astronomers at Alor Star, Kedah, but some photographs of the corona were obtained. The results of the other expeditions have not been fully worked up yet. The form of the corona has been described

by some as of the maximum type, by others as of an intermediate type. More than fifty years ago it was noted that there was a connection between the phase of the sun spot cycle and the form of the corona. Broadly speaking, at a maximum the surrounding corona is more uniformly distributed around the disk, whereas at minimum it is elongated in the equatorial regions and with short little brushes emanating from the poles. As data could only be accumulated at total solar eclipses, our information grew slowly, but using the photographs to date, Ludendorff and, later, Mitchell, have measured the eccentricity of what may be called the coronal boundary, one radius distant from the limb. At maximum, as just stated, it is zero; a year or so before minimum it is 0.30. Mitchell looks upon the coronal spectrum as predominantly solar, the radiation having its origin in the electron, the coronal light bearing the same relation to our sun as the nebulosities which are kindled into luminescence by high temperature stars associated with them.

Coronal Brightness. It has been generally accepted that the total brightness of the corona is one-millionth of that of the sun or about half that given by the full moon. According to an announcement card from Harvard, Stetson at the total solar eclipse of May 9 last measured the brightness as 1/33,000 of that of the sun, a figure considerably higher than previously accepted.

Elements in Sun. A by-product of the revision of the wave lengths of Rowland's Tables of Solar Wave Lengths has been an increase in the number of elements known to be present in the sun. The identification of solar lines with those of elements found upon the earth rests primarily upon comparison of wave lengths, but not wholly so. Recent progress in our knowledge of the ionization behaviour of many elements and series relations in spectra enable us to know what lines to look for once the principal lines have been identified. In such ways St. John and his collaborators at Mount Wilson have established the presence in the sun of 58 of the 92 possible elements. Freeman thought he had identified argon in the corona, but Russell and others refute the idea.

Age of Sun. Eddington's new conception that dwarf stars radiate energy as well as giants, by reason of their stripped and crowded atoms, gives virtually a longer life to the atom, and accord-

ing to Jeffreys the age of the sun can the more readily be brought into accord with geological determinations.

Origin of Solar System. Theories of world building are always of interest and Jeffreys has recently modified the original suggestion of Buffon to account for the origin of the solar system. Of late the general conception has been that through the close approach of another star, tidal action has pulled the planetary matter out of the original sun. Jeffreys now considers that the observed facts will be better satisfied if an actual collision rather than a near approach had occurred in the long ago. On either theory rotation is imparted to the planets by the return to them of matter torn asunder by the tidal action of the sun at their perihelion passages. On the newer assumption the periods of rotation of the larger planets would be of the order of 8 hours, a value more in agreement with observation than values deduced from the near approach theory. Under the older hypothesis the possibility of such an encounter was exceedingly small; with the newer actual collision theory the chances are naturally very much smaller so that, if the collision theory be the correct one, solar systems like our own must be exceedingly rare in the universe.

Moonlight. Minor researches have been carried on upon the light of the Moon. Danjon, with an ingenious cat's-eye photometer, has compared the earth-shine with the light from the illuminated crescent and finds the former much bluer in quality. This earth-shine is sunlight which is reflected to the moon from our earth, principally from our atmosphere. Since it is bluer than ordinary moonlight it must have been less scattered; consequently our atmosphere is not so rough a reflector as the moon's surface, a finding of course quite to be expected. The earth's albedo is given as 0.29, a figure much less than previous values.

Millman and Keenan have investigated the light of the eclipsed moon taking advantage of the total lunar eclipse of Nov. 27, 1928. Keenan photographing through four colour filters from ultra-violet to infra-red finds light of all wave lengths diminished in intensity to about 1/10,000th of its normal value with the red and infra-red rays weakened slightly less than the others. Millman finds the red increased in intensity with respect to the blue as the moon comes out of the umbra.

Moon's Atmosphere Negligible. Following out his general colour survey of the brighter planets and the moon, Wright has photographed the latter object in ultra-violet and extreme red light. One recalls that in the case of Mars, which has a considerable atmosphere, the details of its surface which were brought out on plates sensitive to the infra-red were completely obliterated on the ultra-violet photographs. While such a difference is not to be expected for the moon, due to its well-known lack of an atmosphere, yet it was thought possible that there might be a diffusion of light of short wave length which would tend to soften the intense blackness of the shadows so characteristic of the moon's surface. The conclusion reached was that there seemed to be no difference between the photographs; the blackness of the shadows was as great in ultra-violet light as that of the extreme red. Thus we have confirmatory evidence of the complete absence of any atmosphere surrounding the moon.

Earth's Rotation Period Variable. Irregularities in the moon's motion have of late years been connected with a variable rate of rotation of the earth upon its axis. Confirmatory evidence seems to be forthcoming from similar, though much smaller, residuals in the sun's longitude as tabulated from Greenwich observations of the past 150 years. The new reduction leads to a much closer resemblance between the curves of solar and lunar residuals than has previously been obtained, and thus strengthens the hypothesis that the cause of these fluctuations lies in the earth's rotation, not in the bodies themselves.

Markings on Jupiter. Marked changes of late have been occurring in the surface markings of Jupiter. Last year a long series of small, dark spots occurred in the south equatorial belt with a rotation period of 9h 59m. As the average rotation period of the planet is four minutes less, these were moving *eastward*. The last few months have witnessed a revival of activity in the north temperate zone, a belt of spots extending over half the circumference, and having a rotation period of 9h 49 m showing that they had a general *westward* motion on the surface. They appear similar to the great train of spots which appeared in 1880 and which in a month's time came together to form a new belt.

It has been suggested that a huge, cold atmosphere of hydrogen, and perhaps helium too, overlies the surface of Jupiter, as it has been shown by the radio-metric measurements at Flagstaff and Mt. Wilson to have a surface temperature 150 degrees below zero Centigrade. Perhaps a study of the newly formed belts may help to throw some light on the constitution of this planet's atmosphere.

Minor Planets. About 100 new minor planets are being discovered yearly so that the total number at the end of 1929 is of the order of 1,300. On September 26 one was discovered with a rapid motion, which later was found to have a period of 4.375 years, and which at perihelion passage comes within the orbit of Mars. Using the 36-inch telescope of the Lick Observatory and the one-prism spectrograph, Bobrovnikoff finds the light of the asteroids is wholly reflected sunlight. There seems to be evidence that the composition of the asteroids differs among themselves as judged by the colour of their reflected light.

Meteors. Luyten has examined the Great South African find of iron and pronounced it to be a genuine meteorite. Its mass is of the order of 50 tons and thus it is the largest known. Olivier is quoted as saying that most of the meteors observed are moving in hyperbolic orbits and thus originate, not in the solar system, but somewhere in space.

New Comets. Four new comets were discovered during 1929, (a) by Schwassman and Wachmann in the course of photographing minor planets at Bergedorf; (b) by Neujmin at Simeis, August 2; (c) by Forbes at Cape Town, August 1; and (d) by Wilk at Cracow, December 21. The second has a period of 10.79 years while the third is 6.44 years. A good list of all the periodic comets having periods less than 170 years is given in *l'Astronomie* for May last.

Origin of Comets. Bobrovnikoff has discussed the statistics of 94 comets and has found a relation between the period and the brightness. Long period comets are the brightest, as if frequent returns to the sun caused the dissipation of the light-giving possibilities of the comet. The indicated rate of loss of light leads to the conclusion that comets are not original members of the solar system but have become attached to our system at some time in the immed-

iate past. He suggests a million years ago as the time of capture when our solar system was passing through the nebulous regions of Orion. One possibly ought to accept the conclusions with reserve but the connection between period and brightness is very interesting.

Heights of Aurorae. Störmer obtained good photographs of aurorae for height at three stations on March 15 last. The highest rays extended up to 700 km., where they were in full sunshine. Their lowest points were found to be on the boundary between sunlit and dark atmosphere. Lower rays were also observed. Some commenced in sunlight, became invisible near the boundary and deeper down in the shadow again became visible apparently where the density of the air is great enough to excite luminosity.

2. The Stellar Universe

Velocities of A-type Stars. In the latter part of the year there were issued the Yerkes results for the radial velocities of 500 stars of A- type, brighter than the sixth magnitude. Many of these have been under observation for some years and nearly one out of every three is known or suspected to be binary in character. Eight spectrum plates on the average were made of each star. Some three dozen observers or measurers have co-operated in the programme which was started about 1901. There are 265 stars in the list for which the Lick Observatory have also published results and the Yerkes are on the average 2.3 km. more positive than the Lick. Considering only 56 stars with many good lines this discordance decreases to 0.8 km. so that Frost and his co-authors believe their results are systematically 1 km. too positive.

In this connection brief mention may be made of the writer's own work on the A-type stars which deals with those within reach and brighter than 6.5 magnitude. While primarily intended for absolute magnitudes, nearly all have been measured for radial velocity. Including those obtained on the first Boss programme, between 1100 and 1200 are now available.

San Luis Catalogue. A catalogue of 15,333 stars has been published by the Carnegie Institution of Washington, giving the positions and magnitudes of these stars observed by Tucker and

his associates at San Luis in 1911, as part of the Albany programme under Boss.

Parallaxes. Several lists of parallaxes have been issued during the year. Mention may be made of Alden's list of 50, being some of the first fruits of the Yale Southern Observatory. His redetermination of Alpha Centauri by modern methods gives a parallax of 0".757, almost identical with earlier results.

A list of dynamical parallaxes has been issued by Russell and Miss Moore. Owing to the recently established relation connecting mass with absolute luminosity, the masses of binary stars can be more closely estimated than formerly was the case, and as the parallax varies only as the cube root of the mass, such parallaxes are now considered the equal of the spectroscopic. Fairly good values can be obtained even when only a portion of the visual orbit has been completed.

Scutum Cloud. A study of the distances of galactic clouds is always of interest as affording a comparison with the condensations in the spiral nebulae. Many determinations have been made of the distance of the Scutum Cloud, in the brightest region of the Milky Way. The results varied between 1,500 and 7,000 parsecs and the need for a more rigid determination has long been felt. By determining spectral types both directly and by colour indices, and also obtaining the photographic magnitudes down to the limit of 18 mag., Krieger, at the Lick Observatory, has made a new determination on the usual assumption that the range of absolute magnitude within each spectral subdivision is small. As 1950 stars were used in his discussion his resulting value of 2,800 parsecs for the distance ought to be entitled to considerable weight.

Southern Milky Way. Pannekoek has issued from Lembang, Java, an extensive dissertation on the southern portion of the Milky Way. Numerous drawings are reproduced showing the brighter stars and the background of faint ones, and estimates of the brightness at various regions are given.

Distribution of A, K and B Stars. The same author, in a Memoir from the University of Amsterdam, his own University, deals with the space distribution of the A, K and B stars. As the basis of his work he uses the Henry Draper Catalogue from which

counts of stars of the A and K divisions were made between magnitudes 4.25 and 8.25. Assuming the average absolute magnitudes of the A-types as 0.9 and of the K0-type, 0.7, after the dwarfs were eliminated, he deduced the corresponding distances of the various groups into which he had divided them. The B-type stars having a greater dispersion, had to be treated individually, using mean absolute magnitudes for each subdivision as given by Adams and Joy at Mount Wilson. His general aim is to determine the density distribution. He finds many well-known groups of B-type stars and every such group is at the same time a condensation of A stars. On the other hand there are many A-type condensations from which the B's are entirely absent and in these latter groups K-type stars are found to be very abundant.

Variable Stars. Considerable work has been done upon variable stars not only upon their light curves, but theoretical work which seems to indicate that the difference between the short-period variables, the Cepheids and long-period variables is only one of degree. Observational results and light curves are given by Jordan for 16 eclipsing variables.

Period-spectrum Relation. Adams and Joy, using 64 Cepheids and 44 long-period variables, with a number also of the cluster type, showed that, barring minor discrepancies, there was a linear relation connecting length of period with the type of spectrum involved. The cluster type variables with periods averaging half a day, are of fairly early type, the Cepheids with periods of a week or so, are of solar type, whilst long period variables of one or two hundred days are reddish m-type stars.

Distinct gaps occur between some stars, which are somewhat bridged over by Gerasimovic in his discussion of eleven stars of the RV Tauri type of varaible.

Shapley, with extensive new data at Harvard, discusses the period-spectrum relation anew and concludes that the pulsation hypothesis can be logically extended to the long-period variable as well, on the basis of the observed similarity with Cepheids in bolometric absolute magnitude, radiation variations, spectral peculiarities and galactic distribution.

Gerasimovic discusses 76 M-type variable stars, showing emis-

sion for which proper motions and radial velocities are known. Using these to deduce absolute magnitudes, he finds that the absolute luminosity diminishes as the period increases. Periods less than 250 days give an average absolute magnitude –2.3, whilst those greater than 340 days yield +0.3. Such would seem to disprove their similarity to Cepheids or if the Cepheid period-luminosity relation were considered to hold for them, they would seem to be on the descending branch after a maximum had been reached. Probably the data are too uncertain and meagre to consider the results dependable and, as Gerasimovic points out, the absorption bands play an unknown part.

While not strictly an investigation of the past year, McLaughlin's finding is of interest that the time of maximum light of a variable coincides with the time of maximum velocity of approach more closely as the five-day period is reached. The departures from coincidences in the times increase as we go each way from the five-day periods, the average one for true Cepheids.

The Star 12 *Can. Ven.* Miss Anger at Dearborn Observatory, by means of tracings with the Moll recording microphotometer, has studied the changes in intensities of the lines of the bright star 12 Can. Ven. In addition to the lines of the rare earth elements europium and terbium previously known to vary, she has found that the calcium 3933, the magnesium 4481, and the silicon pair 4128, 4131, also vary.

Belopolsky remarks on changes that have occurred in the spectrum during 1927 and 1928 in the coming in of emission bands and bright borders to absorption lines. It would seem that the star partakes somewhat of the character of a Cepheid.

Stellar Radiation. Measurements of stellar radiation by means of sensitive thermo-couples have improved much the past year or so. Thermo-couples weighing only 1/1,000 of a drop of water are in use with the 100-inch telescope at Mount Wilson, by which it is possible to measure variations of a millionth of a degree in a star's radiation. Betelgeuse, which sends us the most radiation of any star, deflects the spot of light from the recording galvanometer fully 18 inches, yet such deflection means an increase in the temperature of the thermo-couple of only 0.015 Centigrade.

Andromeda Nebula Studies. Hubble has continued his study of the Andromeda nebula and has given us detailed results based upon 350 photographs with the 60 and 100 inch reflectors at Mount Wilson. No indication of resolution into stars has been found for the nuclear regions, but the intermediate and outer regions are partially resolved. Forty Cepheids with periods from 10 to 48 days conform to the period-luminosity law and yield a distance of 275,000 parsecs, practically 900,000 light-years. By this survey the number of photographically observed novae was increased from 22 to 87. Our galactic system is larger than the Andromeda spiral, but the ratio is not greater than between it and other extra-galactic ones.

Lindemann had previously made the suggestion that the brightness of the spiral was due simply to reflected light from the galaxy. Markov finds this cannot be so as its surface brightness is 76 times that of our galaxy so that while our own is large in size it is of low luminosity.

Luminosity of Planetary Nebulae. From trigonometric measures Van Maanen had deduced absolute magnitudes for the planetary nebulae of +8.1. Gerasimovic attempts to show that these parallaxes are too large and that the planetaries should be about three magnitudes brighter. One method is based upon proper motions and radical velocities, another on how they fit in on the assumption of galactic rotation, while the third depends upon their departure from the plane of the Milky Way. It is hard to decide where the error exists and one must await new data.

Similar discordances arise in the distances of dark nebulae determined by Gyllenberg and Lundmark by star counts. The former finds the dark nebula near S Monocerotis at 250 light-years distance; the latter puts it thirteen times as great.

Shapley and Miss Ames, exploring the rich nebular region near the pole of the galaxy, find the main assemblage of spirals at ten million light-years. Three other adjacent "clouds of galaxies" are fainter, smaller, and therefore, more remote. The correlation between magnitude and angular diameter suggests that space is perfectly transparent.

Dimensions of Universe. The dimensions of the universe,

using the term in the larger sense, has been a theme upon which there has not been unanimity of opinion. It was early noted from the Flagstaff radial velocities of spirals that they were large and predominantly velocities of recession. On De Sitter's cosmogony, distant objects would show a recession increasing with remoteness. This is ascribed to a slowing down of atomic vibrations and to a general tendency of material particles to scatter. Reference was made in the last summary to a velocity of N.G.C. 7619 by Humason of +3779 km. per second. On De Sitter's theory, this would yield a distance of 25 million light-years. It was planned at Mount Wilson to secure velocities of more of these faint spirals and three have now been obtained of faint spirals near the pole of the galaxy, two of which have velocities of recession about double the one just alluded to. The corresponding distance of the group is 50 million light-years. The third velocity is not in as good an accordance, and the spiral may not belong to the group.

Silberstein's Views. Silberstein takes direct issue with Hubble, considering as absurd a value for the curvature of space of 140 million light-years as deduced by the latter. From a discussion of 35 O-type stars, 29 Cepheids and 246 distant stars from Young and Harper's list, Silberstein early in the year concluded that space is finite and with a radius of 5 million light-years. A few months later he used in addition 460 more of our stars and obtained 5.74 million light-years. The greatest possible distance apart of two objects would then be nine million light-years. Thus there is marked disagreement and the writer does not feel competent to express an opinion on the discordance.

Belopolsky thought such an effect should be traceable in stellar velocities and while he found positive velocities to increase markedly with distance this has a more rational explanation in the rotation of the galaxy.

Rotation of the Galaxy. Mention was made in the summary of a year ago of evidence tending to substantiate the idea of our galactic universe being in rotation. The programme of the radial velocities of B-type stars, upon which Dr. Plaskett and Mr. Pearce have been engaged since 1924, has recently been completed at Victoria. The results for 500 stars, many of them exceedingly remote,

and therefore correspondingly suitable, were thus available for putting the hypothesis to a rigid test. While all the stars showed the desired trend to the residual velocities, yet it is most plainly seen in those more than 2,000 light-years away, and when the 250 odd stars in this category were subdivided into groups on the basis of distance and longitude in the galactic plan, there was no doubt of a definite trend to the residuals. At mean longitude 10° they have a positive maximum of +24 km./sec; at 55° they pass through zero and reach a negative maximum of −28 km./sec at 100° longitude; again they go through zero at 145° and approach a second maximum at 190°. The observed velocities follow so closely those that would be expected from a rotation that there seems no reasonable doubt that such is the true explanation.

Moreover, similar confirmatory evidence is furnished from the velocities obtained from the interstellar clouds of calcium that permeate all space. On the assumption that the most distant stars will show the strongest interstellar absorption lines, the stars can be grouped on the basis of distance, and again, it has been found by Struve, Oort, and more definitely by Plaskett and Pearce, that this interstellar medium shares the rotation of the stellar universe. That such interstellar material is uniformly distributed throughout space is inferred from the fact that the rotational term is approximately half that of the corresponding stars, corresponding to the centre of gravity of the material between the star and ourselves.

Hub of Universe. The assumption of galactic rotation presupposes a massive nucleus about which rotation takes place, and reference was made in my last summary to the work at Harvard of hunting for the hub of the universe. Photographs of the region in Sagittarius where the nucleus is supposed to exist, reveal sufficient dark matter to obscure a mass sufficient to account for the observed rotation. At its edges, however, according to Shapley, our galaxy is completely transparent, permitting the observation not only of the most distant stars of our own system, but also the outside galaxies, probably millions of years beyond the farthest edge of our galaxy.

The K-term. Another by-product of the Victoria velocities of the faint B-type stars is the vanishing of the so-called K-term for

stars fainter than 5.5 magnitude. It still persists in the case of the brighter B-type stars, about 390 in number, and has the approximate value +5.3, slightly higher than the value of Campbell, who first drew attention to it. The early explanations of this term as due to errors of measurement or of wave length, Einstein shift, and other causes, must be abandoned, for such should be operative in faint as well as in bright stars. A more rational explanation is that it represents a systematic drift of the near by helium stars, most pronounced in certain southern groups.

Wolf-Rayet Stars. Beals, at our own observatory at Victoria, has added to our knowledge of Wolf-Rayet stars. He has secured spectra of all within reach, namely 28, some of them as faint as eleventh magnitude. The width of the emission bands he finds proportional to the wave length and he interprets this as a Doppler effect. In brief, the emission bands are due to the continuous ejections of atoms from the high temperature star. While millions of tons of matter are thus lost yearly, so great are the masses that millions of years would elapse before a variation in the light could be detected.

3. Physical Theories

Stability of Stars. Jeans finds that gaseous stars are unstable, so the very existence of stars implies substantial deviations from gas laws. This is rather disconcerting, but Gerasimovic believes that Jeans failed to take ionization into account, and if this is done, then, with a few exceptions among the massive stars, which may be partially in the liquid state, the dwarfs, giants, and even supergiants, are stable in the gaeseous state. Pannekoek, who was with us at the Victoria observatory for six months the past year, thinks Gerasimovic in turn has omitted something in his formula.

Contours of Stellar Lines. The first 25 years of this century may be said to have concerned itself primarily with the positions of the lines in stellar spectra. From such measures of position have come an extensive knowledge of the radial velocities of stars, and through these in turn, we know of the larger movements of the parts of the universe relative to the whole. Succeeding years will

undoubtedly see greater attention given to the character of the lines themselves, their widths, their intensities, and the relation between the two. Theory states that a stellar line should decrease in darkness from the centre outward, fading into the continuous spectrum gradually. Studying the curves which show how the intensity falls off in these wings at different distances from the centre of the lines, it is possible to calculate the number of atoms which are at work in producing the line. By such studies on the lines in the solar spectrum, Unsöld, a young German physicist who visited Victoria the past summer, has given us some ideas concerning the abundance of the elements in the solar atmosphere. Calcium vapour makes up possibly five per cent. of the sun's atmosphere. In general the intensity of the lines will be proportional to the abundance of the absorbing atoms.

Stark Effect. Of other causes operative to produce the widening of stellar lines, what is known as the Stark effect, has received considerable attention the past year. In 1906, Stark suggested that electric fields surrounding a radiating atom might be expected to produce perturbations, and seven years later, observation showed that under the influence of an electric field spectral lines actually broke up into components. Under strong fields the components are numerous, and blend into one broad line. As the effect is most pronounced for elements of low atomic weight, it has been thought that the great widths of the Balmer lines in A-type stars, or the helium lines in B-type stars, might be due to such an effect. Struve has examined a number of spectra of suitable stars, and finds the Stark effect a contributory, but not sufficient, cause of the broadening. The Stark effect is absent in highly luminous stars where the pressures are very low; it is only in the compact dwarfs that the electric fields are strong enough to produce broadening. Thus broad, fuzzy line stars are dwarfs; sharp, intense lines represent giants in agreement with the Mount Wilson discovery.

Similar work is in progress at Harvard College Observatory, where Miss Williams, studying the contours of A-type stars, finds the lines growing progressively wider for their depth as we pass to the less luminous stars.

4. New Equipment

I discussed rather at length last year the matter of new equipment. Considerable progress has been made this year in connection with the proposed 200-inch telescope in the making of test disks of quartz of increasing aperture. One of 22 inches diameter has now been successfully cast, and it is expected that no insuperable difficulty will be met with on that score. For those who desire more details the November, 1929, number of *Harper's Magazine* will give them.

Two 24-inch refractors, one visual and one photographic, mounted on one tube, have been installed at Lembang, Java.

The 36-inch reflector for the Royal Observatory, Edinburgh, has been completed and installed. It is patterned after our Victoria instrument, and is to be used to study the intensities and positions of spectral lines.

I stated in my summary of last year that the 41-inch refractor had been installed in Russia. A visiting astronomer was emphatic as regards its completion, but from correspondence with Grubb, Stokely assures me it is not finished. I wish to make this correction.

The foregoing summary is necessarily incomplete, and none better than the writer recognizes its rather scrappy character. It is hoped, however, that in some way it will supplement the one given last year, and between the two, attention will be drawn to some of the advances in the science of the past couple of years.

Dominion Astrophysical Observatory,

Victoria, B.C.,
January 6, 1930.

ANNUAL GENERAL MEETING OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The meeting was held at 8 p.m. on January 14, 1930, in the Physics Building of the University of Toronto. Professor R. K. Young, Ph.D., first Vice-President acted as chairman of the meeting.

The minutes of the last Annual Meeting having been printed were taken as read and confirmed.

The General Secretary, Dr. L. Gilchrist, presented the reports of the various Centres,—Montreal, Ottawa, Toronto, London, Winnipeg and Victoria, B.C. The Assistant General Secretary presented the report on the general Membership of the Society.

These reports were received and approved.

Reports were presented from the General Treasurer, the Librarian, the Curator and the General Secretary, all of which were read and adopted.

The ballots cast for the officers for the ensuing year were submitted. Dr. J. B. Fraser and Mr. J. R. Gibbs were requested to act as scrutineers to count the ballots. A vote of thanks to the auditors, Mr. A. R. Hassard, and Dr. J. B. Fraser was adopted, and they were requested to act for the coming year.

The result of the election of officers for 1930 was announced by the scrutineers and confirmed as follows:—

Honorary President—J. S. Plaskett, F.R.S., Victoria, B.C.
President—H. R. Kingston, M.A., Ph.D., London, Ont.
First Vice-President—R. K. Young, Ph.D., Toronto.
Second Vice-President—Mgr. C. P. Choquette, M.A., Montreal.
General Secretary—L. Gilchrist, M.A., Ph.D., Toronto.
General Treasurer—H. W. Barker, Toronto.
Recorder—E. J. A. Kennedy, Toronto.
Librarian—C. A. Chant, Ph.D., Toronto.
Curator—Robert S. Duncan, Toronto.
Council—D. S. Ainslie, M.A., Ph.D., London; R. E. DeLury, M.A., Ph.D., Ottawa; F. Napier Denison, Victoria; Miss A. Vibert Douglas, Ph.D., Montreal; R. A. Gray, B.A., Toronto; E. A. Hodgson, M.A., Ottawa; John Patterson, M.A. Toronto; J. A. Pearce, M.A., Victoria; John Satterley, M.A., D.Sc., Toronto; L. A. H. Warren, M.A., Ph.D., Winnipeg.

During the past year the retiring President, Mr. W. E. Harper, made arrangements with the Southam Press Service to publish in

Canadian journals and newspapers special articles on astronomical and astrophysical science of interest to the general public. These articles have been well received, and have been highly successful in stimulating interest in astronomy and kindred sciences. They have also provided an additional source of revenue for the Society. The following articles have been published:

"The Autumn Skies" by C. A. Chant.
"The Ottawa Meeting" by R. M. Stewart.
"The Rotation of the Universe" by J. S. Plaskett.
"The Distances of the Stars" by H. R. Kingston.
"Sun Spots" by R. E. DeLury.
"How the Velocities of Stars are Measured" by W. E. Harper.
"Mirages" by A. S. Eve.
"The Winter Skies" by A. R. Hassard.

The Honorary President of the Society, Dr. J. S. Plaskett, F.R.S., has been awarded recently the Gold Medal of the Royal Astronomical Society for outstanding work in astronomical science, and has also been appointed to deliver the George Darwin Lecture of the Royal Astronomical Society for 1930.

It is a matter of deep regret to report the deaths of the following members of the Society: J. M. Clark, K.C., Toronto; Henry Harrison, M.A., Jersey City; A. H. Read, and F. R. Lineham, Victoria; H. S. Winchester and W. A. Graham, Ottawa; E. T. White, D.Paed., London.

LACHLAN GILCHRIST,
General Secretary.

MEMBERSHIP OF THE SOCIETY

The membership of the Society on December 31st, 1929, as shown by the Reports of the different Centres, was as follows:—

	1929	1928
Toronto	269	263
Ottawa	61	57
Victoria	113	100
Montreal	112	95
Winnipeg	54	37
London, Ont.	39	40
	648	582

	1929	1928
Honorary Fellows	11	11
Life Members	13	14
Foreign Members and Subscribers to *Journal*	59	50
	731	657

EVA M. BUDD,
Assistant Secretary.

LIBRARIAN'S REPORT

During the year 1929 the Library received a considerable number of accessions both in periodicals and occasional publications, and in bound books.

The Assistant Librarian has supplied the following statistics:—

Number of periodicals received during 1929:

From Canada and the Empire	184
From the United States	199
From other countries	195
	578

The *Journal* was sent in exchange to addresses in:

Canada and the Empire	45
The United States	49
Other countries	46
	140

These numbers are almost the same as for last year.

Among the books added (other than periodicals) were:—

T. C. Chamberlin, The Two Solar Families, 1928.
S. A. Mitchell and C. G. Abbot, Fundamentals of Astronomy, 1928.
George Parson, Discovery of the Earth, 1929.
W. J. Luyten, The Pageant of the Stars, 1929.
W. M. Smart, The Sun, the Stars and the Universe, 1928.
J. H. Jeans, Astronomy and Cosmogony, 1928.
J. H. Jeans, Eos, or the Wider Aspects of Cosmogony, 1929.
J. H. Jeans, The Universe Around Us, 1929.
A. S. Eddington, Science and the Unseen World, 1929.
J. A. McWilliams, Cosmology, 1928.
R. A. Sampson, Science and Reality, 1928.
H. Jeffreys, The Earth, new edition, 1929.
Mary Proctor, Romance of the Comets, 1926.
Mary Proctor, Romance of the Sun, 1927.
Mary Proctor, Romance of the Moon, 1928.
E. Van Cleef, The Story of the Weather, 1929.
E. E. Free and T. Hoke, Weather, 1929.

The accommodation is entirely inadequate; the Society greatly needs better facilities for its office and its library.

C. A. CHANT,
Librarian.

SECRETARY'S REPORTS OF THE CENTRES OF THE SOCIETY

Toronto

The present membership of the Toronto Centre is 269. During the year 32 new members have been added, 4 resignations have been received, 8 names have been removed from the list—dues having been unpaid since 1927. Three members have moved, but failed to notify the secretary of their present address, mail matter being returned by the P.O. authorities; leaving a net gain in membership to the Toronto Centre of 17.

It should be noted that a standing committee on membership has been elected. The appointment of the strong committee, with Mr. F. T. Stanford as chairman, assures the Society of more activity in this direction during 1930. We believe we may safely predict a much greater gain next year.

A more definite organization for the Society's activities in Toronto was thought advisable, and to this end the following offices were proposed: Honorary President, President, Vice-President, Secretary, Assistant Secretary or Recorder; with four Standing Committees,—viz., Finance, Programme, Membership, Building. The Programme Committee to be composed of the President, Vice-President and Secretary.

It may not be generally known to the membership at large that there is held by the General Council a sum amounting to $3,688.00, which is set aside for the purpose of establishing Headquarters of the Society, with a proper place to house the library and telescopes, also an observatory where the instruments could be at the disposal of its members and friends for observational research. It is quite obvious that a building of this kind would give to the science of astronomy in Toronto a great impetus. While the sum at our disposal at the moment is too modest for a building of the kind required, yet it is conceivable that a live committee, working earnestly, could make a start, and perhaps interest the aid of some wealthy persons. Members for offices and committees should be elected for one year. The Programme Committee's activities should, of course, extend over the first period of the following year. The

need for this is very evident, as the programme is arranged for three months in advance.

The following meetings were held during 1929:—

January 15—Annual General Meeting.

February 12—The Society's "At-Home".

March 12—"Photographic Views of the Moon's Surface Formations", by Curator R. S. Duncan.

March 26—"Under the Northern Cross with Allenby in Palestine", (Illustrated), by Lieut. J. H. Hornung.

April 9—"More about Light", (Experiments), by Prof. J. C. McLennan.

April 23—"Gravitation and the Motions of the Planets", (Illustrated), by Charles Lane Poor, of Columbia University, N.Y.

May 21—Open Air Meeting. Telescopes on the University Campus.

October 8—"Meteorites". (Exhibits.) Professor C. A. Chant.

October 22—"Analysis of Light." (Some recent developments), by B. G. Whitmore, B.Sc.

November 5—Amateur Night. "Telescopes we have made". Messrs. A. R. Hassard, H. L. Rogers, D. B. Marsh, and J. R. Collins.

November 19—"The Mathematical Prelude to the Theory of Relativity" by Professor A. T. DeLury.

December 3—"The Tides". (Illustrated). Professor R. K. Young.

December 17—"The Night Sky". (Experiments and Illustrations), by H. J. C. Ireton, M.A.

E. J. A. KENNEDY,
Secretary.

OTTAWA

During the year 1929, 6 public lectures were given by the Ottawa Centre in the Lecture Hall of the Victoria Memorial Museum, as follows:—

Feb. 1st—In Quest of Scientific Data, by R. Glenn Madill, B.A.

Mar. 1st—13 Months in 1933, by C. C. Smith, B.A.

Mar. 22nd—The Signs of the Zodiac, by Dr. A. Vibert Douglas.

Apr. 26th—Astronomy and the Amateur, by John H. Ogden.

Nov. 1st—Earthquakes, Natural and Artificial, by L. Don Leet, M.A.

Nov. 29th—What is a Star? by R. Meldrum Stewart, M.A.

This summer the American Astronomical Society held their 42nd semi-annual meeting in Ottawa from Aug. 26-29. The sessions for papers were held at the Dominion Observatory, and the members of our Society had the privilege of attending these, and hearing papers on various astronomical topics by noted astronomers.

In connection with these meetings, on Aug. 28th, Mr. J. W. Fecker gave an address in the Museum Hall under the joint auspices of the A.A.S., and the Ottawa Centre, R.A.S.C., on "Engineering in Astronomy".

On April 12th, a most enjoyable Soirée was held at the Dominion Observatory, to which the members and their friends were invited. This evening was made possible through the kindness of the director, Mr. R. M. Stewart.

The paid up membership list now stands at 63. This year we are sorry to report the death of two of our members, Mr. J. B. Milliken and Dr. W. A. Graham.

Six new members have joined the society; one has been transferred to the Montreal Centre; one has resigned; and one has become a life member.

This year the custom was adopted of sending the members notes of current astronomical events and also the Saturday night programmes issued by the Dominion Observatory.

M. S. BURLAND,
Secretary.

MONTREAL

During the season 1928-29 eight meetings were held, seven in the Macdonald Physics Laboratory by the courtesy of the Director, Dr. A. S. Eve, and one in the Mechanics Institute by courtesy of the Directors. The general public were invited to every meeting. The following lectures were delivered:—

1. "Comets", Mr. R. M. Motherwell, Dominion Observatory.
2. "Ice Ages in Canada", Dr. A. P. Coleman, Toronto.
3. "The Solar System and the Milky Way", Dr. A. Vibert Douglas.
4. "The Constellation", Mr. E. E. Bridgen, Montreal.
5. "The Relation of Light to Matter", Dr. J. C. McLennan, Toronto.
6. "Tides", Professor A. H. S. Gillson.
7. "Gravitation and the Relativity Law", Dr. Chas. Lane Poor.

During the year thirteen new members were elected, and six were dropped due to non-payment of fees or registration or death. The Society has lost by death three of its members, Mr. Geo. Sample, Mr. Jas. A. Wright, and Dr. E. S. Bieler. The membership now stands at 112.

A. VIBERT DOUGLAS,
Secretary.

London

The present secretary took over this office on June 10th, 1929, after the untimely passing of Dr. White, whose loss has been so keenly felt by all the members, particularly by the present secretary who finds it no easy task to give the society the clear-cut reports of its meeting that it has been used to.

During the year the Society held eight regular meetings, all of which were very well attended. The subjects under discussion were as follows:—

Jan. 11:—"Venus; Our Present Evening Star" by Dr. H. R. Kingston, accompanied by a practical exercise by all the members in the construction of a heliocentric map.

Feb. 8:—"Photographic Analysis of Celestial Objects" by F. H. Coates, F.R.A.S. Lantern slides were used to demonstrate this.

Mar. 8:—"Meteors and Meteorites" accompanied by lantern slides, by Rev. R. J. Bowen, F. R. G. S. Mr. Colgrove also gave a very interesting demonstration of an ingenious planetarium made by himself.

Apr. 12:—This meeting was to have been Dr. White's, but on April 6th he suddenly died and the members had no heart to take up any business except to resolve itself into a memorial meeting.

May 10:—An observation meeting was held on the Campus of the University of Western Ontario.

Oct. 11:—"What the Spectrum Reveals about the Stars" accompanied by quite an elaborate demonstration of the spectrum and spectroscope, by Dr. D. S. Ainslie, M.A., Ph.D.

Nov. 8:—"Evolution in Our Solar System" by Dr. H. R. Kingston, which particularly stressed the orderliness of march of the planets around the sun, and the inconceivably great odds against this order "just happening".

Dec. 13:—Annual meeting and election of officers. A very interesting contest was held on the recognition of the constellations and a lunch was served in the Normal Shcool.

H. S. Wismer,
Secretary.

Winnipeg

During the year 1929 the Winnipeg Centre held seven regular meetings in the University of Manitoba. These meetings were open to the public, were well attended, and an increasing interest was shown in the study of astronomy.

Seven new members were elected and one resignation was received. The membership at the present time is fifty-four.

The following papers were given at the monthly meetings:

Jan. 9th—"Volcanic Activity", Prof. G. M. Brownell, Ph.D.
Feb. 20th—"The Language of Astronomy", Dr. L. A. H. Warren.
March 13th—"Exact Time", Right Rev. T. W. Morton.
April 10th—Members' Night. Ten Minute Talks:
"Antares", Mr. J. H. Kolb.
"Locating an Observatory", Mr. C. E. Bastin.
"April Stars", Mr. A. W. Megget.
"The Solar System", Mr. James Bastow.
"Teaching the Stars by Radio", Mr. D. R. P. Coats.
"Reminiscences of my first lessons in Astronomy", Mrs. J. C. Howey.
Oct. 23rd—"Island Universes", Dr. L. A. H. Warren.
"A Great Hobby", Mr. A. W. Megget.
Nov. 13th—"The Interior of the Earth", Dr. J. S. DeLury.
Dec. 11th—"Double Stars", Dr. L. A. H. Warren.

The Officers for 1930 are:—

President—L. A. H. Warren, M.A., Ph.D., F.R.A.S.
Vice-President—N. J. MacLean, M.D., F.A.C.S.
Treasurer—Mr. J. H. Kolb.
Secretary—Mrs. J. Norris, 569 Sherburn St., Winnipeg.
Council—Messrs. C. E. Bastin, D. R. P. Coats, A. W. Megget, Mrs. J. C. Howey, Right Rev. T. W. Morton, Mrs. E. L. Taylor.
Auditors—Mr. C. E. Bastin, Mr. James Houston.

S. C. Norris,
Secretary.

Victoria

The number of members on the nominal roll of the Centre at the beginning of the year was 100. There have been 3 deaths, and 13 resignations; 28 new members have been elected, and 1 member transferred from the Winnipeg Centre. The total membership of the Centre is now 113.

In addition to the ten regular meetings of the Society, three Council meetings, and several observation meetings were held. The latter were held once a month during the summer, and proved highly successful.

The record of the regular meetings, with the dates, subjects and speakers, is as follows:

January 15—"New Observatories", W. E. Harper.
February 12—"Spectroscopy", Dr. C. S. Beals.

March 12—"Double Stars", R. O. Redman.

April 9—"Stellar Influences", Kilbee Gordon.

April 30—"The reflecting Telescope,—How to make one". A Symposium led by Messrs. J. Duff, W. E. Harper, F. Moore and Dr. J. S. Plaskett.

September 17—"Astrology; Its Influence on the Development of Astronomy", Prof. A. Pannekoek, University of Amsterdam.

October 8—"Phosphorescence and Fluorescence", Dr. G. M. Shrum, University of British Columbia.

October 29—"Long Distance Weather Forecasting", F. Napier Denison.

November 19—"Post-War Developments in Surveying Instruments and Methods", J. E. Umbach.

December 10—"The Rotation of the Galaxy", J. A. Pearce, Annual Meeting of the Society.

In the spring term observation periods followed the regular meetings. In the fall, programmes of the meetings were printed and distributed to all members.

In addition to these regular meetings, the Lecture entitled "Our Wonderful Universe", illustrated by Dr. C. A. Chant's slides, has been given in 14 different places throughout the province, by the Rev. A. H. Priest, West Vancouver; Rev. John Goodfellow, Princeton; J. Duff, Sidney; P. H. Hughes, and J. A. Pearce of Victoria.

A library for the use of the members of the Victoria Centre was founded during the year. Mr. W. T. Bridge, of the Council, kindly consented to be Librarian.

Following the practice of last year, ballots for the election of the 1930 Officers were mailed to all members of the Society in good standing. The scrutineers announced the result of the election, which was confirmed, as follows:

Honorary President, W. E. Harper, M.A., F.R.S.C.; *President*, Dr. C. S. Beals; *First Vice-President*, Dr. G. M. Shrum, Vancouver; *Second Vice-President*, W. Gage, M.A.; *Secretary-Treasurer*, P. H. Hughes, M.A.; *Librarian*, W. T. Bridge; *Council*, G. A. Bucklin, Rev. J. Goodfellow, M.A., Princeton, B.C., J. P. Hibben, R. W. Hunter, Mrs. M. A. Kelk, Alert Bay, B.C.; and past Presidents F. N. Denison, W. S. Drewry, J. E. Umbach, W. E. Harper, J. Duff, M.A., Sidney, B.C., P. H. Elliott, M.Sc., J. A, Pearce, M.A.

WALTER H. GAGE,
Secretary.

LIBRARIAN'S REPORT, VICTORIA CENTRE

During the year 1929 through the energy and enthusiasm of the President, Mr. J. A. Pearce, a library of astronomical and kindred works has been launched. The books, to the number of between 40 and 50, besides a complete set of the Journal of the Royal Astronomical Society, 1907-1928, are varied to suit the tastes of the serious student of the science of astronomy or the reader who prefers somewhat lighter treatment of such subjects.

The majority of the books were presented by Mr. Pearce from his own private collection, while others have been kindly contributed by Dr. J. S. Plaskett, Mr. W. E. Harper, Messrs. Hibben, Duff and others. To all of these generous donors, the Victoria Centre is deeply grateful. It is hoped that from time to time more of such volumes will find their way into this collection, and that the library will become increasingly useful to those more particularly who are unable to attend the lectures of the Centre.

W. T. BRIDGE,
Hon. Librarian.

GENERAL TREASURER'S FINANCIAL STATEMENT,

December 31, 1929

GENERAL ACCOUNT

Receipts, 1929

Cash in Bank, December 31, 1928	$ 932.06	
Grant from Dominion Government	2,000.00	
University of Toronto (50 Journals)	100.00	
Fees of Members	1,490.00	
Subscriptions to Journal and Reprints	202.79	
Southam Press for Astronomical Articles	140.00	
Bank Balance, Guelph Centre (defunct)	10.00	
Bank Interest	53.14	
		$4,927.99

Disbursements, 1929

Publication "Journal" and "Handbook"	$2,395.07
Library Books and Binding	91.19
Salary, Assistant Librarian	540.00
Stationery and Stamps	238.54
Rent of Library and Office	120.00

Grants—London Centre	$ 41.00	
Montreal Centre	187.00	
Ottawa Centre	100.00	
Toronto Centre	217.50	
Victoria Centre	69.00	
Winnipeg Centre	37.00	651.50
Elliott Addressing Machine		79.34
Expenses, "At-Home"		48.00
Miscellaneous Expenses		39.00
Bank Charge re Bonds		2.00
Balance		722.80
		$4,927.99

BUILDING ACCOUNT

Receipts

Balance December 31, 1928	$506.60
Interest, Bonds, $146.25; Bank, $15.59	161.84
Balance in Bank (a/c 4383)	$668.44

LIFE MEMBERSHIP ACCOUNT

Receipts

Balance December 31, 1928	$ 36.51
Interest, Bonds, $5; Bank, $1.49	6.49
One Membership Fee	25.00
Balance in Bank (a/c 4390)	$ 68.00

MEMO OF BONDS HELD BY IMPERIAL BANK

Building Account, Canada Permanent	L 13275	$ 500.00
Building Account Canada Permanent	L 1903	500.00
Building Account, Canada Permanent	L 1913	500.00
Building Account, Canada Permanent	L 3754	500.00
Dominion of Canada	T/E 18682	1,000.00
Life Membership Account Canada Permanent	L 3892	100.00
		$3,100.00

(Signed) H. W. Barker,
General Treasurer.

Audited and found correct, January 18, 1930.

(Signed) J. B. Fraser, M.D.,
A. R. Hassard,
Auditors.

FINANCIAL REPORTS FROM THE CENTRES OF THE SOCIETY

TORONTO

Receipts, 1929

From General Treasurer	$ 217.50
City Grant	100.00
	$ 317.50

Expenditure

Lecturers' Expenses as per vouchers	$ 85.75
Printing and Advertising as per vouchers	95.84
Expenses "At-Home" (later refunded)	48.75
Rent of Room in Physics Building	40.00
Sundries	15.48
Cash in Bank	31.68
	$317.50

Audited and found correct.

J. B. FRASER, M.D.,
A. R. HASSARD,
Auditors.

Jan. 14, 1930.

FINANCIAL STATEMENT FOR 1929

OTTAWA

Receipts

1929		
Jan. 10	Balance on hand	$ 65.64
	Fees collected and deposited during 1929	173.00
	Remittances received from Toronto	100.00
	Int. on Deposits	2.26

Expenditures

1929		
Jan. 27	Postage	$ 1.50
Feb. 25	Postage	1.81
Mar. 13	Notices	2.50
Mar. 23	Expense of Miss Douglas	15.00
Apr. 8	Expense of Soirée	43.00
May 16	Modern Press (Receipt forms)	5.20
July 8	Remitted to Toronto	114.00
July 10	Postage for April 4 and April 16	2.00
Oct. 25	Notices (printing)	3.25
Nov. 22	Stationery and printing	8.00
Nov. 28	Postage and Cards	1.00
Nov. 29	Journal Dailies	3.00
Nov. 29	Evening Citizen	2.80

		Dec. 19 Balance in Bank	137.84
	$340.90		$340.90
Remittances received but not yet deposited	10.00	Balance on hand, December 19, 1929	10.00
	$350.90		$350.90

Examined and found correct.
D. B. NUGENT,
Dec. 19, 1929 *Auditor.*

Balance on hand and in Bank, $147.84
A. W. GRANT,
Treasurer.

MONTREAL

FINANCIAL STATEMENT

Year beginning Nov. 1st, 1928; ending Nov. 1st, 1929

Receipts

Balance carried forward from last year	$ 81.91
1 fee collected for 1927	2.00
12 fees collected for 1928	24.00
85 fees collected for 1929	170.00
1 Life Membership	25.00
Grant from General Treasurer	149.00
Gift from a Member	23.00
Bank Interest	2.91
	$477.82

Disbursements

Remitted fees to General Treasurer	$221.00
Lecture Expenses	52.40
Advertising	3.99
Printing Stationery, Postage	17.65
Janitor Service at Meetings	7.50
Lantern Operator at Meetings	8.00
Exchange on Cheques	0.45
Cash in Bank	166.38
Cash in Hand	0.45
	$477.82

Montreal, 31st October, 1929.
Audited and found correct.

E. EDWIN HOWARD,
W. E. LYMAN.

LONDON

Financial Statement for the year 1929

Receipts

Brought forward from 1928	$ 68.07
Members' Fees	78.00
One member's fee pd. in advance for 1929	2.00
Refund from refreshment allowance	.50
Refund from Toronto (½ 1928 dues.)	41.00
Bank Interest	1.86
	$191.43

Expenditures

Refreshments, annual meeting, 1928	$ 1.39
Supplies for heliocentric map	1.00
Printing notices for 3 months at $2.10 a month	6.30
Postage	.61
Mimeographing programmes	.50
M. E. Willmot, making astronomical slides	14.40
Exchange on cheque from Toronto	.15
Fees to H. W. Barker, Gen. Treas.	78.00
Flowers, receipt books, cartage	6.55
C. R. Smith, setting type for notices	.75
200 post cards, $4.00; plus mimeographing and addressing	7.30
Stamps	2.00
	$118.95

Total Receipts	$191.43
Total Expenditures	118.95
Bank Balance	$ 72.48
Stamps on hand	1.70
Total balance	$ 74.18

H. S. WISMER,
Sec'y-Treas.

WINNIPEG

Year ending December 11th, 1929

Receipts

Balance statement of 1928		$213.57
Cash on hand unreported at close of 1928	$ 6.00	
Bank interest	5.51	
Grant from General Treasurer	37.00	
Subscriptions, 1928	22.00	
Subscriptions, 1929	71.00	
Cash paid in 1928 and repaid to Treasurer	6.43	
		$147.94
		$361.51

Disbursements

Printing	$ 32.50	
Advertising	30.93	
Operation of lantern	9.00	
Watchman	7.00	
Fees to General Treasurer	161.00	
Bank exchange	.59	
Refund of overpayment and deposit	8.00	
Express charges	8.65	
Postage and social	9.55	
		$267.22
Balance in Bank December 11th, 1929		94.29
		$361.51

Audited and found correct.
Dec. 11th, 1929.
(Signed) C. E. BASTIN,
JAMES HOUSTON,
Auditors.

J. H. KOLB,
Treasurer.

LONDON

Treasurer's Report, 1929

Receipts

Bank Interest	$ 2.85
Balance from last year	51.47
Membership Fees	171.00
Grant from parent Society	69.00
Life Membership Fees	25.00
Total	$319.32

Expenditures

Expenses of Lectures	$ 9.02
Janitor's Services and Rent	29.35
Advertising	57.80
Printing	14.77
Stamps and Sundry	8.75
Library	10.00
Remittance to Toronto	146.15
Bank Balance and Cash on Hand	43.48
Total	$319.32

WALTER H. GAGE,
Treasurer.

Audited and found Correct.
W. T. BRIDGE,
Auditor.

WAVES AND PARTICLES[1]

By George P. Thomson

No one who has been so fortunate as to experience the magnificent reception—surpassing even the usual high standard of American hospitality—which you accord to the lecturers of this foundation could possibly begin his duties without a grateful recognition of such splendid treatment. To Mr. George Fisher Baker, the founder of this lectureship, and to Professor Dennis, to whom falls the arduous duty of administration, I want to express thanks which are out of all proportion to what can be expressed in these few words. This foundation is of inestimable value to the men who are fortunate enough to hold it, in giving them insight into the working of one of the most progressive universities of this country and an opportunity of becoming personally acquainted with a group of distinguished men. I have a hard task in attempting to give anything approaching a fair return for these advantages, and I hope you will judge leniently my attempts to do so.

If I break this piece of chalk, then take each of the bits and break them, and so on, is there any theoretical limit to the progress other than that imposed by the coarseness of mechanical appliances? This is a question which has occupied science since the twilight of its earliest dawn.

In the last three or four years opinions have altered as to the best answer to this question. During the first quarter of this century the answer to the question was quite definite. If the piece of chalk is continually broken and rebroken a time comes when the pieces are no. longer merely smaller but become different in kind. This stage can not be reached by mechanical breaking, but it can be reached by heat and suitable chemical action. The chalk has been broken into its atoms. In chalk there are three kinds; other substances would yield other kinds, and, in all, chemists have dis-

[1]Introductory public lecture by Professor George P. Thomson of the University of Aberdeen, non-resident lecturer in Chemistry at Cornell University. Printed in *Science*, December 6, 1929.

tinguished ninety kinds from which all matter is made. These atoms are small. They bear about the same relation to a drop of water that a drop of water bears to the earth. But even here the limit had not been reached. Towards the end of the nineteenth century it had been found possible to break pieces off these atoms: for example, by the violent collision of other atoms. These pieces were always the same. They are called electrons and have now become almost an article of commerce, for they are the working material of the radio valve. The hot filament of the valve gives off electrons as water gives off steam, and the electric forces in the oscillating circuit control the motions of the electrons.

The older view of the electron is best expressed by regarding it as a tiny lump of electricity which had a little mass—less than a thousandth of that of a light atom—as a kind of secondary property of its charge. It was supposed to have a certain extremely minute size, but as a matter of fact the estimate of this size rested on purely theoretical arguments and no one had ever measured it. However, it soon became apparent that each atom contained electrons varying in number from one each to nearly two hundred and fifty each for different kinds of atoms. Thus it was reasonable to suppose that an electron was a good deal smaller than an atom.

Later on—it is difficult to give an exact date—it became clear that there was a second universal constituent and that this was the residue of a hydrogen atom when one electron—the only one—was removed. It has been called the proton. Every atom contains, in its normal state, an equal number of electrons and protons. The protons are much the heavier of the two, but they occupy only a very small region in the center of the atom called the nucleus. This region is so small that the combined nuclei of a man's body would form a barely visible speck. Since the nucleus also contains some electrons these apparently must be at least equally small, and we are left with a picture of matter as mostly emptiness. That such a view is not purely figurative has been shown in a striking manner recently. It seems certain that some stars known as "white dwarfs" are so dense that a cubic inch would weigh a ton. This is still nothing like the density of a nucleus but it shows at least that an ordinary solid must have plenty of gaps if it can be compressed to such an extent.

The picture of matter was thus essentially one of discontinuity. It consisted of a number of specks—of a whole number, for an electron or proton can not be split. It is a return to the earliest philosophy, for it was Pythagoras who taught that "all is number."

But there was another side of physics in which continuity was supreme. If you had asked the question "How does one electron act on another," the answer would have been "through stresses in the ether." Now the ether has had a long and checkered history. Ethers of a sort were common in early physics—rather too common. But the ether first acquired an assured status in the scientific world when it became clear that light had to be explained as *waves*. As this introduces the other half of the title of my lecture you will perhaps allow me to dwell on it in some detail.

The obvious thing about light is that it goes in straight lines—as can be seen if you watch light passing into a darkened room through a small hole and tracing out a path as it lights up the motes of dust. Now Newton said that a particle free from force goes in a straight line. It was natural to suppose that light consisted of a stream of particles shot out by the luminous object. Light can be reflected by mirrors and refracted by glass but, superficially at least, these effects can be explained as a rebounding of the light particles, or their deflection by forces at the surface of the glass, as the case may be. Nevertheless, influential men such as the Dutch physicist Huygens suggested in the seventeenth century that light was a form of wave motion. Now sound is wave motion and every one knows that sound will go round corners. So will water waves. How can you explain the rectilinear propagation of light on this view? It is all a question of the wave-length. Even in sound a high-pitched note is not heard well round a corner. If the wave-length of light is small enough rectilinear propagation is all right. Also light does bend very slightly. The really crucial test is what is called interference, the property by which two lights can produce darkness. A special form of this is to take a number of regular spaced wavelets, all derived from one wave. This gives a peculiarly marked effect. The effects of the combined wavelets are strongly concentrated in a few privileged directions and cancel everywhere else.

Light shows this phenomenon to a very marked extent. For

example, in the case of the diffraction grating, light scattered from a large number of regularly spaced scratches on a glass or metal surface is found to be concentrated in a few directions, and this effect can be used to measure the wave-length of light with very great accuracy.

The ether was required to carry these light waves. At first it was thought of as a kind of jelly, and Lord Kelvin used immense mathematical skill in finding the very peculiar type of jelly which alone gives exact agreement with the experimental laws of light. Now Faraday long before had regarded electric and magnetic effects as stresses in a medium, and Maxwell showed that the same medium could do double duty, carry electric effects and transmit light. Hertz crowned the theory by actually producing waves by purely electromagnetic processes which had the velocity of light, and in fact were invisible light: "light" whose wave-lengths were to be measured in meters instead of thousandths of a millimeter as are those of the visible kind. I need hardly say that these waves are those now used in radio. Later it was shown—not until 1913 indeed, but logically it comes in here—that X-rays are invisible light, on the other side as it were. Their wave-length is about 10,000 times shorter than that of ordinary light instead of millions of times longer. The way in which this was proved is of interest. To show interference well, one needs an apparatus so exactly shaped that the errors are smaller than the wave-length to be tested. Now X-ray wave-lengths are smaller than most atoms. It is impossible to shape an apparatus exact to an atom. Von Laue got over the difficulty in a very ingenious way. He remembered that in a crystal the atoms are arranged in regular order like soldiers drawn up in close formation. The result is a series of lines like a diffraction grating and about the right distance apart. Actually it is a little more complicated because the atoms are arranged in a solid array, while an ordinary grating is on a plane, but this does not really matter. The result of sending X-rays through a crystal is a diffraction pattern, and in this way the wave-lengths can be found.

So far, then, we have matter made of discontinuous particles, while the interaction is due to a continuous medium which can transmit waves. But now came the difficulties. I will take two selected

ones which are enough to show their nature. When light is allowed to fall on a polished metal surface, electrons are thrown out from the metal. Since light is electromagnetic waves and electrons are electrical, it is not surprising that there should be an action of this kind, but the details are all wrong. The speed with which the electrons come out does not depend on the intensity of the light. They come out with just the same speed for the feeblest light as for the strongest, only there are fewer of them. Now if, for example, sea waves are breaking on the beach and rolling the pebbles about, the more violent the waves the farther the pebbles are thrown. If the water waves behaved like light, an almost calm sea would throw a few selected pebbles as violently as a great storm throws them all. This is obviously contrary to one's ordinary conception of waves, and it is equally at variance with the results of a complete mathematical treatment. Moreover, the energy with which the selected electrons appear is so great that they would take hours to absorb it from feeble light, while even with the feeblest light there is no detectable lag between switching on the light and the appearance of the electrons. Obviously something is wrong. Einstein suggested that the light contained units of energy or quanta which behaved practically like particles. When one collides with an electron it gives up its energy to the electron which then can escape from the metal. All the quanta in a given kind of light are the same, but the stronger the light the more numerous they are. The energy of each quantum is the frequency of the light multiplied by a quantity "h," which can be found by measuring the energy of electrons emitted by light of known frequencies. This has been done by Professor Millikan. He finds $h=6.55\times10^{-27}$. Now this is all very well for the photoelectric effect, as the above is called, but what about the diffraction grating? We have just decided that light must be waves and now it turns out to be particles instead, for it is essential for the explanation that the quanta should be so concentrated that one electron can catch a whole quantum. This is the famous photoelectric paradox.

Before I try to answer it, I will describe the other difficulty. Atoms can be made to emit light, and each atom emits its own characteristic wave-lengths. These are clearly a consequence of the

structure of the particular atom, presumably of the arrangement of its electrons. Now one theory, and one only, was found capable of explaining these wave-lengths even in general terms. This was the theory due to Neils Bohr according to which the electrons were supposed to move in orbits round the nucleus rather like planets round the sun. But in order to make the theory fit the facts, Bohr had to assume a behavior of the electrons which is quite contrary to ordinary dynamics, and curiously enough the same quantity "h" came in, though in quite a different way. The real trouble was not so much that the electrons obeyed different laws from those of Maxwell and Newton, but that they were not consistent about it. Some of the things they did required the old laws to explain them; others required a new and inconsistent set. Sometimes both had to be used in different parts of the same calculation. The position of a physicist investigating an atom was rather like that of a man trying to make sense of an account of a game which started as golf and suddenly for no apparent reason turned into tennis and then back to golf again. Worse still, as time went on it became clear that the electrons did not play fair even at the game they had for the moment chosen. The results were nearly right but not quite. The only hint was that the quantity "h" came in whenever the atom chose to break the old rules, and this suggested a connection with the photoelectric paradox. The first really successful attempt to solve these difficulties is due to Prince L. deBroglie. He realized that the reason why the electron in the atom seemed to follow two different sets of rules at once was that it was behaving much more like a wave than a particle. Now if you think that you are reading an account of a game played with a ball, when really the reporter was writing about a swimming match, it is not to be wondered at if the report does not make good sense. It is perhaps surprising that the physicists made as much of it as they did. DeBroglie's theory was a mathematical one based on relativity. He reached the conclusion that any moving particle would be accompanied by a wave, and he postulated that this wave controlled the motion of the particle. Instead of Newton's laws of motion (motion in a straight line, acceleration proportional to the force, and so on) this view gives a motion governed by waves. Of course Newton's laws are true in every-day life. This is be-

cause a very short wave is indistinguishable in behavior from a particle, and the scale of deBroglie's waves is given by "h", which is a very small quantity. But according to his theory the smaller the particle the longer the wave. For an electron in an atom the wave is quite comparable with the size of the atom, and the behavior of the electron is greatly different from what you would expect of a particle. It has been found in fact that this theory when fully applied mathematically as it has been by Schrödinger and others brings order out of chaos in the explanation of the properties of atoms.

Further, it is capable of dealing with the photoelectric paradox. Granting that there are in fact quanta, or particles, in radiation, they will inevitably be accompanied by waves which will guide them. The quota will appear where the waves are strong; where there are many quanta the light will be intense. In other words, the regions of brightness and darkness will be just those predicted on the wave theory. This way out had indeed been suggested before. It turns the flank of the difficulty by saying that it is the natural way for a particle to behave. But if you accept this you must be prepared to take the consequences. A free electron, such as a cathode ray, should also be guided by waves and should also show diffraction. How could we hope to detect it if it did? Calculation shows that the wave-length of a free electron of manageable energy is of the same order as that of X-rays. Can not we use a method similar to that by which the waves of X-rays have been measured and take advantage of the regular structure of crystals?

Successful experiments on these lines have in fact been made by Dr. Davisson and Dr. Germer in this country and by myself and others in Scotland. In my own experiments a narrow beam of fast electrons, cathode rays, in fact, pass through a very thin film of metal. The metal scatters the electrons, and since metals consist of a number of minute crystals, the scattering occurs predominantly in certain privileged directions, just as is the case with X-rays. Accordingly, if the electron strikes a photographic plate placed somewhere behind the thin film we should expect to get a pattern similar to that produced by X-rays of the same wave-length. This expectation is in fact realized. I have obtained these diffraction

patterns from a considerable number of metals. In all cases the patterns are in exact agreement with what is to be expected if they are regarded as the result of diffraction of waves by the known crystal structure of the particular metal used. The patterns are in general formed of concentric rings just like the familiar Debye-Scheerer X-ray powder photographs. From the sizes of the rings it is possible to deduce the wave-length of the waves causing them, and I find in all cases absolute agreement with the theoretical expression due to deBroglie, $\lambda=h/mv$. Thus instead of being scattered irregularly by the metal, it appears that if the film is thin enough it will guide the electrons into the directions which would be taken up by waves diffracted from the crystal structure of the metal.

If you accept the experiments as showing that electrons behave as if guided by a train of waves, you will agree that deBroglie's idea brings a remarkable simplification. Both electrons and light quanta are on the same footing as particles guided by waves. The difficulties of physics in the earlier years of this century were due to ignorance of this dual character. For some reason we had got hold of the wave aspect of light and the particle aspect of electrons, and were running each to the exclusion of the complementary view. It also explains the curiously confusing nature of the difficulties. If we had neglected, say, the wave aspect in each case, all the new facts would have pointed to waves. As it was, some pointed to particles and some, as we now know, to waves.

This dual aspect of things as waves and particles must be very fundamental in the world. There is little doubt that protons would show it also, though experimental proof has so far not been possible. There is even strong, though indirect, evidence that a completed atom has a wave as a whole as well as component waves for its individual electrons. One reason for regarding the duality as really fundamental is that it holds for such different things as electrons and quanta. For in spite of this one point of resemblance they are essentially different. The electron has electric charge and hence is influenced by electric and magnetic forces in a way that the quantum is not. The quantum always goes (*in vacuo*) with a speed of 300,000 kilometers a second. The electron can go with any speed,

provided it is less than this. For equal wave-lengths the penetrating power is quite different. These differences make it all the more significant they should both show the same curious duality. The new view is not by any means free from difficulties. To take the most obvious, many electrons form part of each of the atoms of a crystal, yet the experiments I have described essentially involve the idea that the wave of the moving electron is spread over a number of the atoms in the crystal. Have we proved that the part is greater than the whole? I think that even modern physics is not so paradoxical as this. It depends on what you mean by the size of an electron. We can measure the size of atoms in a fairly definite way by finding how many can be packed into a given space of solid. It is rather like measuring the size of shot by counting how many will fill a cartridge case of known volume. Of course we have to allow for possible empty spaces between, but this can be done if we know how they are piled together, and in many cases we do. The sizes are not quite definite; they vary a little with circumstances, but this is not surprising. Suppose that you want to know the size of a tennis ball. It is easy enough to measure it to an accuracy which will satisfy the authorities at Wimbledon that it is legal, but if you were asked to give its diameter to a hundredth of an inch there would be difficulty. Are you going to measure it to the furthest-out hair of the felt? Obviously that is not a very important measurement, but where are you going to stop? There is no sharp edge. Here a rough measurement has a real and useful meaning, but if you try to make it precise beyond a certain point it can be done only by making some arbitrary convention, such as how hard the measuring instrument is to press. This is the case of the atom, but for the electron the size is even less definite. It has not got even an approximate boundary, as far as our present knowledge goes. It is more like a gas which can expand to "fill" (in a sense) any vessel into which it is put, and yet can be compressed into a very small space. When an electron is part of an atom, its waves curl round, as it were, on themselves until it occupies only the atom, and perhaps only a part of that. When it gets free from the atom as a cathode ray, or escapes from the filament of a valve, its waves can uncurl and expand indefinitely. I think, however, that in all cases one must con-

sider it as also having a sort of centre, even if this is only a mathematical point. Whenever an electron produces any detectable effect it does so as a particle, and it seems easiest to suppose that even when it is not producing an effect the particle is somewhere round. The best analogy I have been able to find for this view is a gossamer spider.

When this little animal is clinging to the stalk of a plant, it is a small solid object. When it wants to move it shoots out long filaments many times its own length. The wind catches these and wafts it away. I regard the filaments as analogous to the waves which surround the electron, while the body of the spider is analogous to the central point. One can press the analogy further. If the wind carries the spider so that one of its filaments is caught in an obstacle, the spider will be swung around and its path deflected although its body has not hit anything solid. In just the same way with the electron, if its waves pass over an obstalcle, say an atom, the direction is modified and this modification is transmitted back through the wave system to the electron itself. If we suppose that the electron is constrained always to move in a way determined by the waves in its immediate neighborhood, the motion of the electron itself will thus be modified. The waves thus act as a kind of intermediary between the disturbing objects and the electron itself. The electron goes where the waves in its immediate neighborhood carry it, just as the spider is pulled by the parts of the filaments which are actually attached to it. But the form of the waves, near the electron, is determined by events at a distance, whose effects are propagated through space in the form of waves.

A question that inevitably arises is—what is the medium which transmits electron waves? I am sorry that I can give no entirely satisfactory answer. For the first time, physics is faced with waves in empty space which do not fit into the ordinary series of ether vibrations. All the ether vibrations differ only in wave-length; if the wave-length is given, the kind of "light" is fixed. The electron waves have varying wave-lengths depending on the speed of the electron, but they usually fall in a region of wave-lengths which is already appropriated by X-rays. As we have seen, they are certainly not the same as X-rays. One must suppose some other

medium, or at least that the ordinary ether is in some way profoundly modified by the presence of the electron. It is possible that they are waves in a "subether." But it is not a very attractive idea to have two ethers filling space, especially as the waves of protons, if they exist, would demand yet a third. Space is getting overcrowded. Other suggestions are to regard the waves as a kind of mathematical abstraction, a sort of ghost waves. The whole question is getting very metaphysical. Perhaps a simple physicist may be content as long as the waves do their job of guiding the electron, and it is possible that, after all, the question will ultimately be seen to be meaningless. Whatever the medium is, the new wave conception has altered the view we take of the best answers to the question with which I began this lecture. Matter is still supposed made of discrete units, but instead of these units moving by laws which concern them alone as did the laws of Newtonian dynamics, we have had to introduce laws based on waves. Now a wave is essentially a continuous thing, even if the continuity is only mathematical. It is spread through space, not divided into little lumps. So although the older belief in the discontinuity of matter still holds, it has lost some of its rigidity; continuity has crept in by the back door.

The idea of the ether has also changed. The sole function left it is to guide the quanta; they do the work. The picture of light as waves breaking on a shore of matter, and thus disturbing it, is replaced by one of a stream of bullets which affect only the particular objects which they hit. The bullets, it is true, do not move quite as ordinary bullets would; they are directed by the waves, but all the effects are bullet effects, not wave effects.

We have seen that Newtonian mechanics needs modification; that it is a simplification which is permissible only when the wavelength is very small. This of course does not detract from its practical value in every-day life and in astronomy, nor from our estimate of the genius which gave it a form which has satisfied two and a half centuries. On the contrary, the new developments, as far as they concern light, which I have tried to explain to you at such length, are much better expressed in the words of Newton's *Optics*:

> Those that are averse from assenting to any new discoveries but

such as they can explain by an hypothesis, may for the present suppose, that as stones by falling upon water put the water into an undulatory motion, and all bodies by percussion excite vibrations in the Air; so the Rays of Light excite vibrations in the refracting Medium or Substance . . . that the vibrations thus excited are propagated in the refracting or reflecting Medium or Substance, much after the manner that vibrations are propagated in the Air for causing Sound, and move faster than the Rays so as to overtake them . . . and that every Ray is successively disposed to be easily reflected or easily transmitted by every vibration which overtakes it. But whether this Hypothesis be true or false I do not here consider.

After being regarded for generations as an artificial attempt to save a dying theory, we have proved this guess of Newton's to be a supreme example of the intuition of genius.

THE SPECTRUM OF 12 CAN. VEN.*

By W. E. Harper

Considerable investigation has taken place on the spectrum of this bright star to whose peculiar nature attention was first drawn by Miss Maury at Harvard over thirty years ago. Its type is given as Aop and lines of peculiar wave-length were present in its spectrum. Ludendorff, in 1906, noted that some of these were variable in intensity.

In 1913, Belopolsky independently discovered the variability, finding two groups of lines, one group increasing in intensity as the other decreased, the period being 5.5 days. As certain of the lines showed variable radial motions in the same period, Belopolsky postulated a gaseous shell in revolution about a massive nucleus.

Using the wave-lengths as given by Belopolsky, Baxandall ascribed the unknown lines to europium, one of the rare earth elements. This being the case, Fowler, realizing the sensitive character of this element spectroscopically, suggested that slight disturbances in the atmosphere of the star would be sufficient to put the substance in or out of the absorbing layer and thus account for the waxing and waning of the lines.

The next year, 1914, Guthnick and Prager found the star to be a variable with a light range of .05m.

Kiess, at Ann Arbor, made an exhaustive study of the spectrum from fine-grained plates of single prism dispersion and a few of the Lick three-prism plates. He corroborated Belopolsky's discoveries and provisionally ascribed the second group of lines to terbium.

Plates secured by Belopolsky in the years between 1913 and 1920 were studied by Gerasimovic, Rossovskaya and Markov and the intensities measured by means of a scale. Certain new lines were found to vary which previously had been considered to be of constant intensity. A slight correction was obtained to the period, making it 5.4695 days. Later Belopolsky described changes that had occurred in the spectrum in 1927 in the coming in of emission

*Seminar No. 151, D.A.O.

bordering some of the lines. In 1928, isolated emission strips were noted in addition to bright borders of the lines.

Not knowing of the work done by the Russians from 1913 to 1920, as it was printed in the Russian language, Miss Anger, at Dearborn Observatory, felt that a study of the intensities of the lines of this peculiar star by means of the Moll recording microphotometer would be a profitable piece of work. About 50 tracings were made of single prism spectra and on these it was possible to correlate a given deflection of the galvanometer with a known change of intensity expressed in stellar magnitudes. She considered only the depth of the line at the centre; it would appear that much better results would have been secured had areas been used as several lines vary in width as well. The lines 4481 of magnesium, 3933 of calcium, 4128 and 4131 of silicon were new ones found to be variable in intensity. Several also between Hβ and Hγ suggested that other elements than europium and terbium were concerned.

The star thus partakes somewhat of the nature of a Cepheid. It varies in light, in velocity and in the type of spectrum. As time goes on and more attention can be given to a study of spectra now secured, it is quite possible many will be found to be variable which are now considered as constant in spectral type.

REVIEW OF PUBLICATIONS

Météorologie du Relief terrestre: Vents et Nuages, par A. Baldit. 328 pages, 6½×10 in., 128 fig. Paris Gauthier-Villars, 1929.

This book, by a well-known French meteorologist, is due to the progress of aviation which has shown the importance of a better knowledge of the atmosphere. The pilots of the air lines should possess at all times accurate information respecting those atmospheric elements which influence the security and rapidity of the flights. These include the direction of the wind at different altitudes, the height of the clouds, and the distance of visibility. The problems before the meteorologist are immense and complex. This work discusses the influence of the contour of the earth's surface on winds and clouds.

Chapter I is devoted to methods and apparatus. It discusses the kite, the plane (with and without motor), the balloon (of various forms), the influence of mountains, etc. Chapter II deals with the action of irregularities of the earth's surface, such as mountains, valleys and rivers. Chapter III takes up the formation of clouds by natural surface features,—through ascending currents, thermal action, dynamical origin and turbulence. Chapter IV gives examples of clouds produced by terrestrial surface irregularities.

This is a valuable contribution to an intricate branch of scientific investigation.

NEWS AND COMMENTS

In last month's issue it was stated that Asaph Hall, who died last June, was the discoverer of the moons of Mars. Of course, this was a mistake. They were discovered by his father, of the same name, who died in 1907.

Captain C. S. Freeman, superintendent of the U.S. Naval Observatory, has stated to *Science Service* that the observatory has decided to sponsor an expedition to Niuafou Island in the South Pacific, near Samoa, to observe the total solar eclipse of October 21. Dr. S. A. Mitchell, director of the Leander McCormick Observatory of the University of Virginia, and veteran of seven previous eclipses, will head the party. The remainder of the personnel is to be selected, but Captain Freeman especially desires some astronomer who can make photometric observations of the brightness of the eclipse. (*Science*).

Dr. John A. Miller, retiring from active teaching and administrative work at Swarthmore College, will continue in charge of the Sproul Observatory as research professor, devoting attention especially to certain problems connected with the Sun's corona.

The mounting for the 36-inch reflecting telescope of the Royal Observatory of Edinburgh, on Blackford Hill, is nearly completed. The telescope, of Cassegrainian arrangement, will have provision for visual, photographic and spectrographic observations. It is the intention of Professor R. A. Sampson, Royal Astronomer for Scotland, to use the telescope chiefly in spectroscopic investigations, particularly those concerned with the intensities of spectral lines.

At the annual meeting of the Astronomical Society of the Pacific, on January 25, the following Board of Directors was elected for 1930: C. H. Adams, R. G. Aitken, Bernard Benfield, J. Costa, Charles S. Cushing, W. J. Gray, Alfred H. Joy, Clifton H. Kroll, Paul W. Merrill, W. F. Meyer and Horace H. Scales. Just after the meeting the Board of Directors met and the officers elected were as follows: President, Dr. William F. Meyer; first vice-president, Clifton H. Kroll; second vice-president, Prof. Alfred H.

Joy; third vice-president, Bernard Benfield; secretary-treasurer, C. H. Adams.

From *Popular Astronomy* we learn that the University of Texas has recently come into possession of somewhat more than 800,000 dollars bequeathed to it by the late W. J. McDonald, of Paris, Texas, for erecting, equipping and maintaining an astronomical observatory. The University will proceed very carefully and slowly to plan for the future McDonald Astronomical Observatory, availing itself of the advice of the most competent astronomers.

Which raises the question: Are there not enough people with surplus wealth in Canada to similarly equip our universities? What offers?

At the recent meetings of the American Institute of Mining and Metallurgical Engineers held in New York, papers were presented by Professor A. S. Eve of McGill University, and Professor L. Gilchrist of Toronto University. Dr. Eve's paper was on "Absorption of Electromagnetic Induction and Radiation by Rocks," and Dr. Gilchrist's paper, "The Theory and Application of a Central and a number of Symmetrically-placed End Electrodes in Electrical Prospecting." Their papers were based on recent investigations that they and Dr. D. A. Keys have been carrying on for the Department of Mines. (A H.M.).

"But let me conjure all who may be contemplating the study of astronomy: *Begin in the open.*"—David B. Pickering.

Start with the Moon :

LIBATIONS AND LIBRATIONS

O, constant Moon!
Thy calm and steadfast gaze
My conscience smites,
Whene'er returning from mine errant ways:
Late, festive nights!

I deemed thee constant!
Till I beheld thine ear aturned,
As though to hear
The chiding thoughts that in me burned:
Turn back thine ear!

REDEL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Further Honour for Dr. J. S. Plaskett

The Rumford Premium has been awarded to Dr. Plaskett. This is a gold medal which is given at irregular intervals by the American Academy of Arts and Sciences, Boston, for researches in heat and light. It is the highest honour the academy can give. The last awards were to A. H. Compton of University of Chicago, and H. N. Russell, of Princeton. Dr. Plaskett will be in Boston early in April and will receive the medal in person.

Astronomers and Observatories

The Royal Observatory of Belgium is preparing a new edition of the book, "Les observatoires astronomiques et les astronomes," which appeared in 1907. This work, which is to be published under the auspices of the International Astronomical Union, will include all active observatories and the names of astronomers, professional and amateur, with an indication of their specialties.

A questionnaire was sent to observatories several months ago; those who have not replied are asked to do so without delay. Professional and amateur astronomers who have not received a request for information are asked to furnish the statement of address, position and special line of work.

Communications should be sent to Director P. Stroobant, Royal Observatory of Belgium, Uccle 3, Belgium.

A Nest of Bright Meteors

There appeared in a Toronto newspaper of February 24 a statement that a bright meteor had been seen on the previous evening by persons in Toronto and near London; and a request for further reports, courteously inserted next day and copied by other papers, brought to the present writer thirty responses by letter and telephone. This was very encouraging and showed the widespread

interest in celestial phenomena, and it also revealed the remarkable fact that not one but four meteors had been seen.

The one most observed was seen at about 9.10 p.m. Reports came in from near Stayner, about 65 miles from Toronto in a direction 34° west of north; from Gormley, about 16 miles directly north; from Welland, about 50 miles directly south; and from near London, about 100 miles south-west: but the estimates of altitude are not accurate enough to permit a determination of the actual height of the body above the earth. Nor do the observations of the other meteors supply a basis for calculations.

The most striking feature of the meteor seen at 9.10 was that it was low down in the sky and travelled at practically the same level all the time. One observer thought it was rather higher at the end, but several others stated that it was a little lower then. The general estimate of altitude in Toronto was 30° or 35°, while a carefully drawn diagram of its path as seen at Gormley put it at 40°. It is unfortunate that its position among the stars was not noted by any observer. That would have fixed the altitude at once.

As seen in Toronto the meteor first appeared a little north of east and its visible course in the sky was about 90° long. It simply disappeared in the south or a little west of south. As the altitude was apparently almost the same when seen from comparatively distant places the body must have been at a considerable distance. It was a brilliant yellow, and its trail in the sky was bright reddish at the middle, bordered by a deeper red, while the very outside portions gave off a bluish colour. One observer described the trail as electric blue. Some declared that the body gave off sparks as it rushed through the air; others did not see them. The head was larger than the brightest stars and while the body moved rapidly it remained in view for some seconds, a common estimate being 15, though that is probably much too high. It may be remarked, also, that estimates of altitude are generally about one-third too high.

Those reporting on this meteor were: Mr. Wilfred Bean, Prof. M. A. Buchanan, Mr. Roland Curtin, Mr. C. E. Fice, Mr. Frank George, Mr. and Mrs. R. Hadley, Mrs. A. A. Hassard, Mr. N. Kelly, Mr. C. F. Leonard, Mrs. Bert Martin, Mr. Douglas McGhee, Mr. George Melling, Mr. J. B. Tegart, Mr. W. K. Wootton, all of Toronto; Mr. Oliver McCort, Stayner; Mr. T. G. Lyon, Gormley;

Mr. L. J. Davies, West Hill; Mr. Harold Reid, Ridgeville; Mrs. Emanuel C. White, Master Howard C. White, and Mr. E. S. Turner, of Welland; Mr. and Mrs. F. Trigger, Mr. H. R. Hill and Mrs. J. A. Watson, of Hamilton; Masters Hughson Miller and Elmo Johnston, London.

From Miss Helen Rogers and Mr. F. A. Harris, Toronto, came reports of a meteor seen at about 7 o'clock, described as "in the north and slanted down towards the east," also "not very high in the heavens; exceedingly bright; crossed the sky from west to east."

Messrs. Joseph Haggas and Alfred Lord, of Toronto, reported that they saw a meteor in the northern sky, crossing from the northwest to northeast. This was between 8.30 and 9, probably near 9. It looked like a brilliant orange-red star with a long tail, at an altitude of 30° to 35°. It seemed to split up at the end.

Mrs. E. L. Hughes, of Trout Mills (near North Bay), about 190 miles north of Toronto, reported that at 7.10 p.m. she saw a meteor cross the sky from southwest to south at an altitude of about 50°. The head was like a very bright star.

A London despatch states that on the same evening while William Lumsden and friends were motoring from St. Thomas to London they saw a large meteor cross the northern sky from east to west. It appeared about as large as a locomotive headlight with a tail of fire streaming after it. The time is not given, and this may have been a fifth meteor on this same evening.

Mr. H. R. Hill, of Hamilton, who reported on the 9.10 meteor, states that he saw a very large meteor at 1.15 a.m., February 14. It was low in the sky, appeared as large as a street lamp, and sparks were leaving it. It moved from south to about 10° or 15° east of northeast; visible 15 to 20 seconds.

Annual Report of the Mount Wilson Observatory

The Report of the Director for the year 1928-29 is a great record of work done and is so condensed that it can hardly be summarised. Some extracts from it will be found interesting.

Among the numerous investigations carried on during the year . . . . is the remarkable character of the results found by Hubble, Humason and Pease for the apparent velocities of the very distant nebulae, and the outlook they afford

upon the nature of the universe of space and time. Simply as results of observation, the discovery of apparent velocities of recession ranging upward to nearly 8000 km. a second is of great interest, but much more significant and of fundamental importance to our conceptions of the universe is the relationship established with a considerable degree of certainty between the magnitude of these velocities and the distances of the nebulae observed. This is of a simple linear character such that one nebula twice as far away as another will show twice as great an apparent velocity. It may well prove that this relationship will ultimately afford the most accurate means for deriving the distances of the extremely remote nebulae. At present, however, its chief interest lies in the fact that it affords an apparently unique criterion for use in forming a judgment upon the two or three great hypotheses of the space-time structure of the universe as a whole. The mathematical complexity of the subject is enormous, and it is still uncertain what portion of the large apparent velocities observed is to be ascribed to actual motion in the usual sense, and what part to the effects of the properties of space. As the most remote objects of which we have any knowledge, however, these nebulae with the phenomena associated with them seem to be the only source upon which we can depend for information regarding what occurs to light as it passes through the depths of space and past the great masses of matter constituting the stars.

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In continuation of his photographic study of the infra-red solar spectrum, Babcock has succeeded with the aid of improved instruments and colour filters in measuring the wave-lengths of over 350 lines between 9867 and 11,634A. The accuracy of the results makes it possible to identify many important lines in this region, including those of potassium, magnesium, calcium and other light elements.

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Some very important and remarkable results have been obtained for the apparent radial velocities of extra-galactic nebulae by Humason and Pease. Three nebulae in the Coma Berenices cluster near the pole of the Milky Way give values of +4700, +7300, and +7800 km./sec., respectively. A nebula in a cluster in Pegasus gives +3800 km./sec., and the three clusters, N.G.C. 3227, 4051 and 6359, which are not members of clusters, have apparent velocities of +1150, +650 and +2800 km./sec.

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A provisional estimate by Hubble of the distance of the Coma Berenices cluster of nebulae indicates a value of the order of 50,000,000 light years. This result is based upon a comparison of the mean apparent photovisual magnitude of the cluster nebulae with the previously determined absolute magnitude (−15.2) of nebulae in general. C. A. C.

MEETINGS OF THE SOCIETY

At Toronto

December 17, 1929.—The regular meeting was held in the Physics Building at 8 p.m. Mr. J. R. Collins in the chair.

Mr. G. Drew-Smith, 18 Chestnut Park Road, Toronto, was elected to membership in the Society.

Mr. H. J. C. Ireton, M.A., gave the paper of the evening, which was entitled "The Light of the Night Sky." Attention was called to the distribution of aurorae and a short summary given of the various theories which have been put forward to explain the phenomenon of the aurora. Reference was made to the work of Störmer in Norway, and the results obtained by him for heights of aurora were quoted. A short sketch of the early observations made on the spectrum of the aurora was given, leading up to the work of Vegard, Lord Rayleigh and Slipher, the results of which indicated the absence of hydrogen and helium, but the presence of nitrogen. The above work applied chiefly to the polar aurora. Attention was drawn to the soft green glow of the night sky which exists at all times in all latitudes when the sky is moonless and cloudless, and even when it is moonlit or partly clouded the spectrum of this light as found by many observers was shown to have been identified with a line in the spectrum of the polar aurora of wave-length 5577A. A description of the laboratory experiments which led to the discovery that this line had its origin in the excitation of atomic oxygen was given. The identity of the oxygen green line with the green line of the aurora was definitely established as the result of accurate determinations of the wave-length by interferometer methods of the green line by Babcock and the oxygen line by McLennan and McLeod. From an examination of the Zeeman effect of the oxygen green line it was shown how this line fitted into one of the spectral schemes of the oxygen spectrum.

An account was given of the experiments carried out by Lord Rayleigh and the Department of Physics at Toronto to measure the variation of the intensity of the green light of the night sky throughout any particular night. The suggestion was put forward that the dissociation of the ozone of the upper atmosphere into oxygen may produce the supply of atomic oxygen required for the emission of the radiation of the auroral green line 5577A. Reference was also made to the work of Dr. Ruedy and Mrs. Krotkov on the height of the ozone layer, and of the work in progress to study the intensity of the green line with the altitude of the observing station. The various experiments carried out in the laboratory, where the amount of energy necessary to excite the green line is measured, enable one to arrive at some conclusions as to what energy is available in the upper atmosphere.

Mr. J. R. Collins then presented the report of the Programme Board of Toronto Meetings for 1929. This, on motion of Mr. A. F. Hunter, seconded by Dr. Wunder, was accepted.

The following were then nominated as officers of the Board of Toronto meetings:—*Honorary President*, Sir Frederic Stupart; *Chairman*, Mr. J. R. Collins; *Vice-Chairman*, Mr. R. A. Gray, B.A.; *Secretary*, Mr. E. J. A. Kennedy; *Treasurer*, Miss Evelyn Watt; *Recorder*, Mr. J. R. Gibbs. *Standing Committees: Finance*, Dr. W. M. Wunder, Mr. A. F. Hunter, Dr. J. B. Fraser, Mr. R. A. Gray, Mr. H. W. Barker and the Chairman. *Programme*, Chairman, Vice-Chairman, Dr. J. Satterly, Mr. E. J. A. Kennedy, Dr. L. Gilchrist and Mr. R. S. Duncan. *Membership*, Mr. F. T. Stanford, Dr. R. K. Young, Mr. J. H. Horning, Mr. J. R. Gibbs, Miss Budd, and Chairman. *Building*, Mr. H. L. Rogers, Dr. C. A. Chant, Mr. A. R. Hassard, Mr. A. D. Armour, Mr. A. F. Miller; with power to add to their number. These were elected unanimously.

January 21, 1930.—A regular meeting was held in the Physics Building of the University. Mr. J. R. Collins in the chair.

The address of the evening was by Mr. J. R. Gibbs, F.R.M.S., on "An Amateur Lecturer on Astronomy in England." Mr. Gibbs explained the difficulty of getting together the necessary slides, narrating visits to Greenwich and Oxford observatories. He explained that most of his lecturing was amongst co-operative audiences, giving several humourous incidents which occurred. Some of the slides used in England were thrown on the screen.

After expressions of appreciation of Mr. Gibbs' address, the meeting was adjourned.

February 18.—A regular meeting was held on February 18 in the Physics Building of the University of Toronto, Mr. J. R. Collins in the chair. The following were elected to membership:

E. B. Birchard, B.A.Sc., 488 Masson St., Oshawa, Ont.
Gilbert C. Tassie, Vernon, B.C.
Miss Annie Hardisty, 124 Dundas St., Brantford, Ont.
M. S. Kovalenko, Swarthmore College, Swarthmore, Pennsylvania.
C. E. Barns, Pacific Science Press, Morgan Hill, Cal.
F. Soulsby, 112A Emerson Avenue, Toronto.

The Chairman said that each evening in the future some constellation would be mapped and explained. Orion was the first chosen, being named after the first king of the Babylonians; the stars and nebula of the constellation were outlined by Mr. Collins.

Mr. Harold Bibby of the Meteorological Service then gave his lecture on "Exploring the Upper Atmosphere." The lecturer gave a brief outline of the history of meteorology, which was divided into five periods. Weather forecasts were first published in Canada in 1879. The upper reaches of the atmosphere were explored by means of kites, balloons and sounding balloons; at first it was thought that the temperature decreased with height, but careful researches show that beyond a certain height there is a rise in temperature. The coldest region

in the upper air is over the equator, the thermometer registering 130° Fahr. below zero, the warmer air being over the poles. The speaker stressed the point that aerial navigation is an ally to meteorology, hence the speeding up of important observational data. Visibility, it was found, was best with a north wind, the dust content then being the least. He mentioned the coming visit of the British air-ship R 101, saying special air stations are being opened, even from Cape Race, so that all air craft will get good service. Slides were thrown on the screen, helping to make clear the various points of the lecture; sample balloons were shown, weighed, and then filled with hydrogen.

Many questions were asked and replied to. Forty per cent. was the loss in balloons sent up with registering instruments. Mr. Bibby said the balloons were Canadian and were in demand all over the world. One point made by the lecturer was the big improvement of the wind indicator and anemometer brought about by the director, Mr. Patterson, reducing the errors of registration almost to zero.

The lecturer was thanked most sincerely for his very able address.

E. J. A. KENNEDY,
Secretary.

AT MONTREAL

February 5, 1930, in the Macdonald Physics Laboratory. The President was in the chair.

New members were elected as follows:—Miss McDougall, Mr. A. L. Fyon, Dr. W. L. Kennedy.

The President called upon Dr. J. S. Foster to introduce the speaker. Prof. Svein Rosseland, Director of the Observatory of Oslo, and special lecturer on cosmical physics at Harvard Observatory during the present year.

Dr. Rosseland took as his subject "Variable Stars," and after outlining briefly the various types of regular and irregular variables, pointed out that any theory advanced to account for one type must be capable of extension to all types of variation, probably also to novae for these problems are undoubtedly fundamentally one.

After outlining various theories which have been suggested and showing their inadequacy, the lecturer discussed the possible line of attack which is based on a study of the convection currents which must arise within a star and the deflections and irregularities to which such currents will be subject due to the rotation of the star. By analogy with the earth's atmosphere, and with the sun's atmosphere certain conclusions seem fully justified and the phenomena of variability appear to be explicable in terms of intermittent turbulence following upon periods of regular convection flow. This offers greater hope of success, in the lecturer's opinion, than to make arbitrary assumptions regarding the source of stellar energy.

A vote of thanks was moved by Dr. A. S. Eve, and after some discussion regarding liquid stars and the opacity factor, the meeting adjourned.

A. VIBERT DOUGLAS,
Secretary.

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The objects of the Society, incorporated in 1890, are:

(*a*) "To study Astronomy, Astrophysics and such cognate subjects as shall be approved of by the Society and as shall, in its opinion, tend to the better consideration and elucidation of Astronomical and Astrophysical problems; and to diffuse theoretical and practical knowledge with respect to such subjects.

(*b*) To publish from time to time the results of the work of the Society; and,

(*c*) To acquire and maintain a Library, and such apparatus and real and personal property as may be necessary and convenient for the carrying into effect of the objects of the Society."

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Ont.; Toronto, Ont.; London, Ont.; Winnipeg, Man.; and Victoria, B.C. Among its 800 members are a number of the leading astronomers and scientists of the world, many amateurs, and in addition, many laymen who are interested in the culture of the science.

Membership in the Society is open to anyone interested in Astronomy. The annual dues are $2.00; life membership $25.00 (no further dues). The annual fee includes subscription to the publications.

The Society publishes a monthly JOURNAL containing about 500 pages of interesting articles, and the yearly HANDBOOK of 72 pages containing valuable information for the amateur observer. Single copies of the JOURNAL or HANDBOOK are 25 cents.

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